PLANNING GRANT

FUSION SCIENCE THEATER: AN INNOVATIVE MODEL TO SOW AND GROW THE SEEDS OF STEM THROUGH COMMUNITY-BASED SCIENCE THEATER

Summative Evaluation

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Your Mind on Media

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Summative Evaluation of Fusion Science Theater Planning Grant

Fusion Science Theater (FST) was founded in 2006 by Holly Walter Kerby, a chemistry/playwriting instructor at Madison Area Technical College (Madison, WI, USA). Informed by her classroom and theater experience and inspired by the work of ISE practitioners throughout the country, Kerby recruited local theater artists, outreach specialists, and science educators to craft outreach shows for children that used theater techniques to provide an active learning experience. FST's first endeavor, "The Amazing Chemical Circus," engaged the audience with three inquiry-based chemistry lessons presented as the acts of a circus. The goals for the Circus were (a) to combine inquiry-based science teaching, demonstrations, theater, and participatory techniques (Act-It-Outs); (b) to engage and educate children 4-11 years of age; and (c) to make it relatively easy and inexpensive to perform and produce.

The popularity and success of "The Amazing Chemical Circus" led to an ISE Planning Grant (with Kerby as PI) with three major goals: (a) to develop the FST model and evaluate the effectiveness of FST shows; (b) to transfer the model by training others to use the FST techniques; and (c) to disseminate this approach by informing and recruiting future adopters of the method.

The specific plans to achieve these goals were as follows:

1. To revise and re-present "The Amazing Chemical Circus," adding an assessment of the audience's engagement/interest, their gains and in knowledge/comprehension, and the show's impact on their attitudes toward science;

2. To develop and present a new, short, mobile show ("Science-in-a-Box") based on the FST model;

3. To transfer the model by having other groups create and perform their own show using the FST approach; and

4. To disseminate information about FST's methods and effects to potential future adopters at conferences and through publications.

This Summative Evaluation discusses the work and accomplishments of the project team toward each of these plans by highlighting the main outcomes and lessons learned. For each of the three shows that were presented, the impact on the child audience was assessed in terms of engagement/interest, knowledge/comprehension, and attitudes toward science. The views of parents and educators who attended the shows were also solicited. In addition, observations were made on the efficacy and success of the collaborative process involved in staging and performing these shows. Finally, this report details the level of success the project has achieved in

disseminating information about the Fusion Science Theater model to potential adopters of the approach and in soliciting their interest in embracing these methods.

1. Revising and Re-presenting "The Amazing Chemical Circus"

A reprise of "The Amazing Chemical Circus" was included in the Planning Grant to ensure that FST could reproduce the success of the original Circus. This goal was accomplished in April 2007. Although the circus theme and general structure of the first "Amazing Chemical Circus" were conserved, a number of changes were made to improve the show: First, the lessons presented in each act were re-focused to align the main educational components (such as the demonstrations and the Q&A) toward a single learning objective. This was done to streamline the content and help the audience understand the concepts being taught. Second, the theatricality of the show was improved by making two changes in the cast: First, a community actor was integrated into the central, host role of the Ringmaster. This freed the PI to focus on the orchestration of the project, and allowed an actor to be included in the performance team. Second, a female instructor was cast in the role of one of the scientists to balance the gender of the demonstrators and to create a role model for girls in the audience. By adding an extra performance to satisfy the demand for tickets, the size of the audience was doubled, which improved the statistical power of the data analysis.

Two in-studio shows were presented. The 160 no-cost tickets for both performances in the Madison Area Technical College Studio Theater were "sold out" by email reservations two days after the event was announced.

Evaluation of "The Amazing Chemical Circus"

Method

As the audience entered the theater, pre- and post-show questionnaires were distributed to children and post-show questionnaires were distributed to parents. For children who were not proficient in reading and writing, parents were asked to assist their children by reading the questions and filling in the child's answers. Questionnaires from 56 children were received (68% were boys). Respondents ranged in age from 2 to 14 (Median age = 6.0). Forty parents filled out questionnaires.

Results

Engagement/Interest. Children gave very positive evaluations of the show. Most said they liked it "very much!" (See Figure 1). Moreover, when asked whether they wanted to come to more shows, 65% chose "yes!," 31% chose "maybe," and only 4% said "no." Most of the children's written comments were enthusiastic (e.g., "very very very cool," "I loved the show," "the scientists were great"; see Appendix A.) In addition, parents gave the show extremely high marks. Seventy-five percent rated the show as "extremely" valuable, and 25% said it was

"moderately" valuable; none chose "a little bit" or "not at all." Similarly, 89% said they were "extremely" interested in bringing their children to more shows and 11% said they were "moderately" interested. (See Appendix B for parents' comments.)

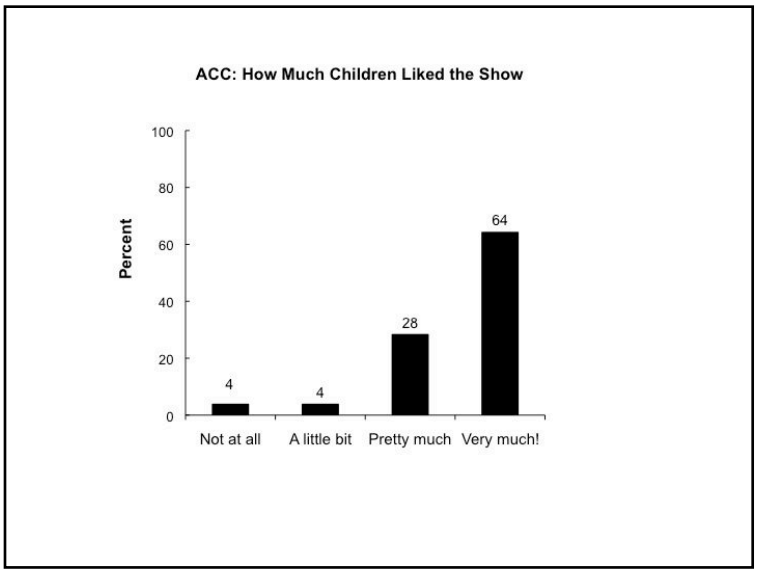

Figure 1. "The Amazing Chemical Circus": Engagement/Interest

Knowledge/Comprehension: Two questions testing concepts demonstrated in the show were included in the pre- and post-show questionnaires. One dealt with polymers; the other dealt with combustion (Figure 2).

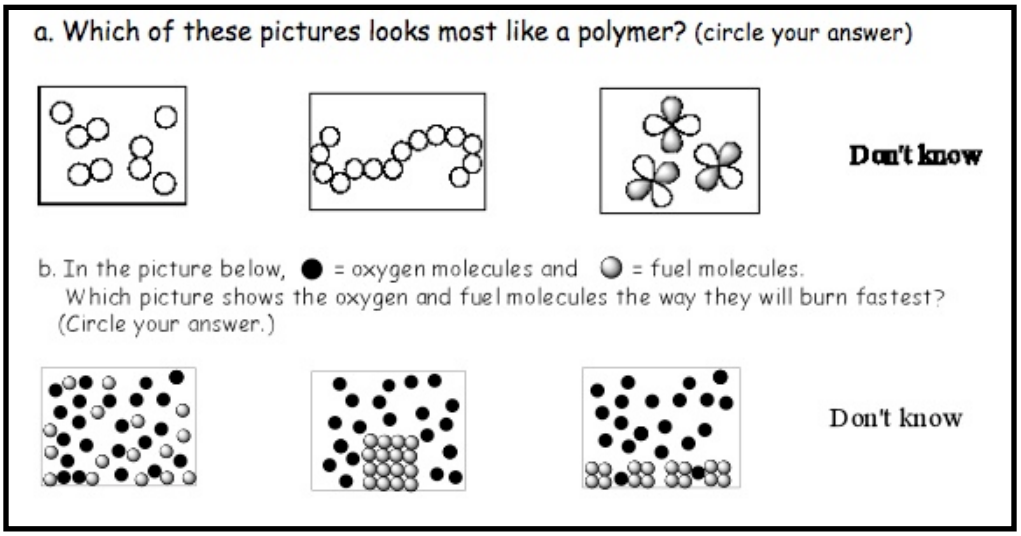

Figure 2. "The Amazing Chemical Circus": Investigation Questions

Answers to these multiple-choice questions were converted to a dichotomous variable indicating that the response was either correct or incorrect. To test for statistical significance, the nonparametric Wilcoxon Signed-Rank Test was used. The percentage of children who answered these questions correctly increased significantly from before to after the show (polymer question: 23 vs 64%, $z = -4.27$, $p<.001$; combustion question: 32 vs 62%, $z = -3.4$, $p < .001$).

Because of the wide age range, responses from children were divided into three age groups of approximately equal size to reflect their presumably increasing background knowledge of science (youngest group, ages 2-5, n = 19; middle group, ages 5.5-7, n = 19; oldest group, ages 7.5-14, n = 18). Figure 3 shows that improvement occurred in all three age groups.

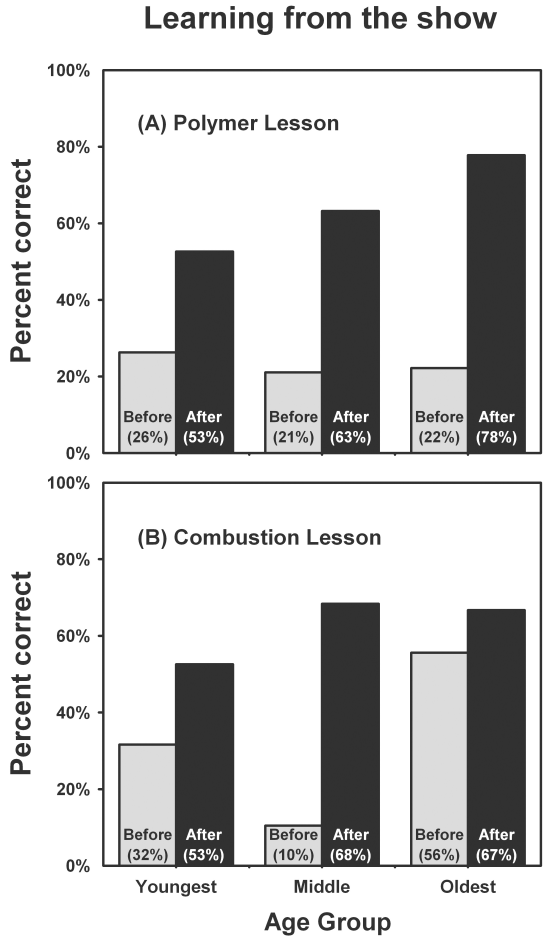

Figure 3. Learning from "The Amazing Chemical Circus": For both lessons with age groups combined, there was a significant pre-post increase at $p<.001$.

Attitudes toward science. Five statements expressing attitudes toward science were rated before and after the show. The attitude statements were "Science is exciting," "I can understand science," "I'd like to learn more science," "I'd like to be a scientist," and "Science is fun." Ratings were made on a scale with a range of 0-3, as follows: 0 = "not at all "; 1 = "a little bit "; 2 = "pretty much "; 3 = "very much!" A "don't know" option was also provided. To determine whether any of these attitudes changed significantly from before to after the show, and whether

any of these changes varied as a function of the child's age, a mixed-design analysis of variance was conducted on the data for each attitude. The age group (youngest, middle, oldest) served as the independent factor and pre- versus post-show assessment served as the repeated-measures factor. "Don't know" responses were treated as missing data.

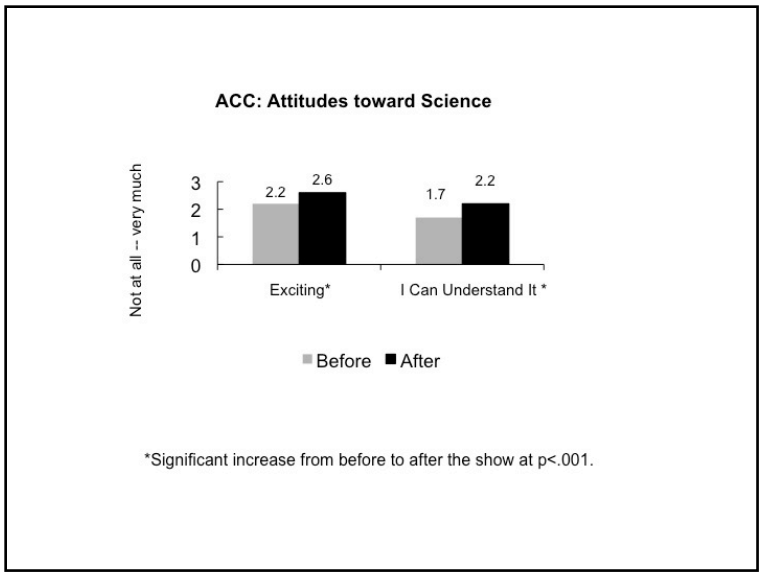

Figure 4. "The Amazing Chemical Circus" and Attitudes toward Science

There was a significant increase in agreement with two of the statements (Figure 4). "Science is exciting" yielded a significant before-after main effect: $F(1,45) = 13.3$, $p = .001$. "I can understand science" also revealed a significant main effect from exposure to the show: $F(1,46) = 18.6$, $p<.001$. In addition, there was a significant interaction between age group and the repeated measure on the "I can understand science" measure: $F(2,46) = 8.5$, $p = .001$. This interaction resulted from the relatively large increase in feelings of competency among the youngest group (youngest, 1.1 vs 2.5; middle, 1.9 vs 2.1; oldest, 2.0 vs 2.2).

Conclusion

"The Amazing Chemical Circus" had no trouble attracting "sellout" crowds, and attendees showed great enthusiasm for attending similar presentations. The show did extremely well in promoting engagement/interest, increasing knowledge/comprehension, and enhancing positive attitudes toward science.

Discoveries and Lessons Learned

In repeating the "Amazing Chemical Circus," the following core principles were identified and refined into a preliminary model: (a) limit the scope of education to a single learning objective for each act; (b) align each demonstration to directly support the learning objective; (c) use a host character to bridge different segments of the show, move it along, and

connect the audience with the science demonstrators. These characters and the show genre provide a framework to allow the science instructors to do what comes naturally (i.e., teach). (d) involve the audience both verbally and kinesthetically to activate different learning styles.

The process of re-presenting the show also demonstrated the value of bringing together science educators and actors in mounting a production. Although the actors' initial lack of science knowledge caused them great insecurity, it also helped the science educators gear their presentation to the minds of the audience. On the other hand, the science educators, who felt considerable anxiety in their roles on stage, benefited from the actors' reassurance and coaching.

2. Developing a New, Short, Mobile Show Based on the FST Model: "The Boiling Point"

The project team used the elements and general structure of the "The Amazing Chemical Circus" acts to create a mobile show that was unencumbered by the technical needs of a traditional stage production. The result was "The Boiling Point," a 35-minute show that investigates molecular-level interactions that occur when water vaporizes. The script used a version of the scientific method as the dramatic structure.

"The Boiling Point" was presented in five locales: Girl Neighborhood Power, an after-school enrichment program; Windsor Elementary School, 4th grade classes; Hawthorne Elementary School, Family Science Night; the Madison Children's Museum (on two dates); and the University of Wisconsin Engineering School, Science Expeditions. These presentations were held between January and April of 2008.

Evaluation of "The Boiling Point"

Method

For evaluation of "The Boiling Point," the knowledge/comprehension assessment was integrated into the show. Children were given a chance to "vote" for what they considered the correct answer to the major concept question by filling out paper "ballots" both before and after investigation of the learning objective. The ballots were collected immediately after each vote was held. In addition, children filled out a post-show questionnaire, which had items assessing engagement/interest and attitudes toward science. Rather than rating their attitudes toward science before and after the show, as was done for "The Amazing Chemical Circus," they rated statements indicating their perceptions of the effects of the show on their attitudes after the show. Parents and educators who attended the presentations also filled out post-show questionnaires. The child questionnaires were filled out by 188 children (47% were boys). The children ranged in age from 2 to 16 (Median Age = 8.5). Starting with the Madison Children's Museum presentations, a box was added to the ballot for children to indicate their age, so that knowledge before vs. after the show could be assessed for different age groups (N = 171). Sixty-seven parents and 12 educators filled out (after-only) questionnaires.

Results

Engagement/Interest. A majority of the children attending these shows said they liked the show "very much!" (Figure 5); 59% also indicated that they would like to see similar shows in the future, and only 4% said that they would not. The children's comments were uniformly enthusiastic (e.g., "I loved it. It was awesome. I want to be a scientist too!" "It is the greatest science show in the history of science shows," "It was awesome. I liked the experiments a lot. They were cool. I would love to see another show"; see Appendix C). Parents were extremely positive in their ratings of the show: 68% said they thought the show was "extremely" valuable and 79% said they were "extremely" interested in bringing their children to more shows. Comments from parents and educators were overwhelmingly positive and enthusiastic (see Appendices D and E, respectively).

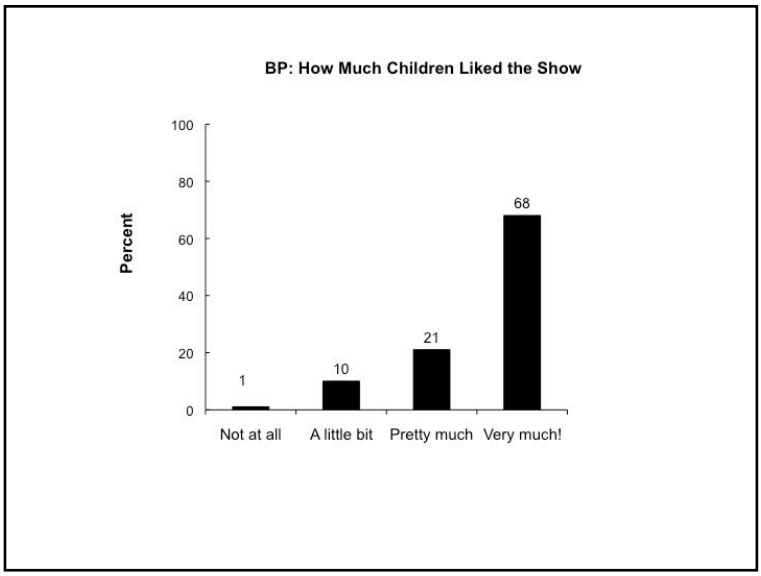

Figure 5. "The Boiling Point": Engagement/Interest

Knowledge/Comprehension. The investigation question was "What happens to the molecules of water when it boils?" (Figure 6 shows how the choices were presented on the ballot.) In every session, the percentage of children answering the question correctly increased from before to after the demonstrations. The improvement is seen most clearly in the analyses from the sites at which children's age was assessed with their answers. Dividing children into three age ranges (2-7, 8-9, and 10-15), the data show that the percentage of children who answered correctly increased significantly from before to after the demonstrations in all three age groups (Figure 7).

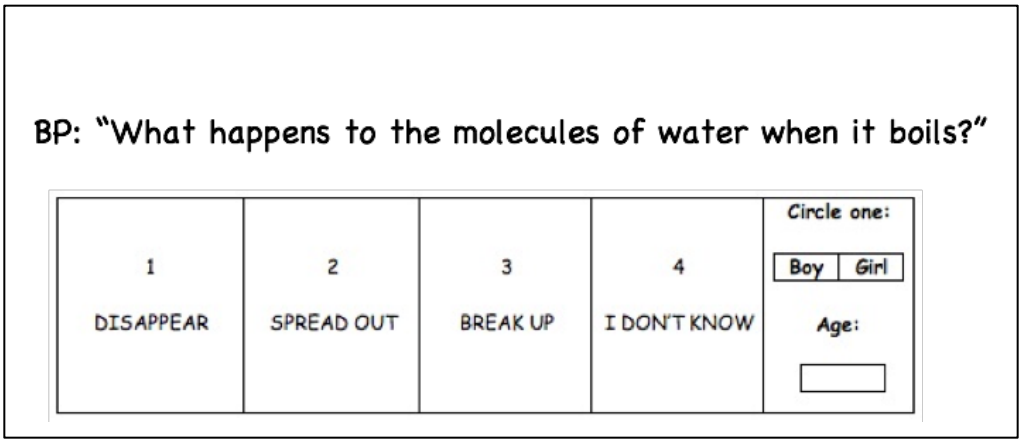

Figure 6. "The Boiling Point" Investigation Question

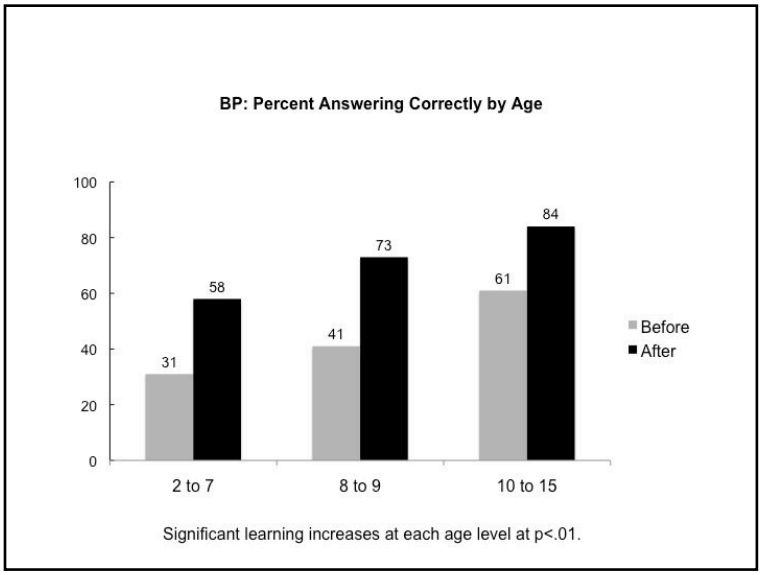

Figure 7. "The Boiling Point": Concept Learning by Age

Attitudes toward science. Children responded to five statements by choosing among "not at all" (0), "a little bit" (1), "pretty much" (2), and "very much!" (3). The five statements (with mean responses in parentheses) were "The show made science seem exciting" (2.3). "The show made science easier to understand" (2.0), "The show made me want to learn more science" (2.2), "The show made me want to be a scientist" (1.6), and "The show made science seem fun" (2.3).

Conclusion

"The Boiling Point" was extremely popular with children, parents, and educators; it increased knowledge at all age levels, and children said it contributed to their more positive attitudes toward science.

The Boiling Point was a success in additional ways as well. Participating partners on the grant, including Rachael Lancor of the UW Wonders of Physics program, were impressed by the structure, focus, liveliness, and effectiveness of the show, and they were eager to begin work on their own scripts. (See "The Circuit Show," below). The FST team was also inundated with requests to perform the show at local elementary schools and for science nights, birthday parties, and festivals. They could honor only a few of these requests, but the strong word-of-mouth demonstrated the great enthusiasm and demand for this type of show.

Discoveries and Lessons Learned

Using the scientific method as plot. By applying the lessons learned from remounting "The Amazing Chemical Circus," the team was able to create a new, mobile, innovative and robust model of science outreach that they dubbed Science Investigation Shows (SI Shows). This model included the theater elements that proved useful in "The Amazing Chemical Circus," including character, genre, and physical dramatizations. It also included pedagogical elements like focusing on a single learning objective, audience participation, and embedded evaluation by concept question. The SI Show model improved on "The Amazing Chemical Circus" by aligning these elements using the same kind of dramatic structure used to hook and engage audiences in a stage play. This dramatic structure consists of a dramatic question and all that follows to answer it (plot). For the purpose of engaging children in science learning, an "investigation question" is substituted for the dramatic question, and the scientific method itself is the plot. With this construction, the investigation question is answered by children's observations of the demonstrations, their participation in kinesthetic models of underlying concepts, and group problem solving. The result is a show that works like a play to engage science learning in a playful, participatory environment.

Embedded assessment. After the introduction of the investigation question ("What happens to water when it boils?"), children were asked to choose what they thought was the best answer to that question by voting for one of four options. This was done again near the end of the show just before the answer to the question was revealed. Embedding evaluation into the show had two advantages. First, it eliminated the need for a pre-show questionnaire. Second, by filling out paper ballots, the children's involvement was secured, and having expressed their opinion, they became invested in finding out the answer, sustaining their attention throughout the program.

Bilingual applications. A pilot bilingual version of "The Boiling Point" was developed to increase the project's ability to benefit under-served audiences. The main adaptations included presenting signs in both English and Spanish and incorporating a translator as a third character. These adaptations were crafted as an integral part of the script. The bilingual approach was chosen (as opposed to rewriting the script entirely in Spanish) because it simplified the development process without sacrificing the intended outcome. Although this performance was not formally evaluated, the performers reported that these adaptations were well received by the audience, which suggests that this approach works and can be used for other shows.

3. Transferring the Model

A. Training Another Group to Create and Perform Their Own Mobile Show: "The Circuit Show"

Wonder of Physics' facilitator Rachel Lancor was interested in developing an FST show that was shorter than "The Boiling Point" and included an independent story line. The project team met with her three times during October 2007 to pick a topic for her SI Show. In these sessions, Lancor presented a number of simple demonstrations on electricity and circuits to the nonscientist team member (Marcy Weiland) and answered her questions. Lancor had already developed and used an activity in which children played the part of electrons in a circuit. The FST group brainstormed ways to frame this ready-made Act-It-Out with a set of demonstrations and a suitable investigation question. In the end, they decided to launch the show with the following Investigation Question: Why do light bulbs wired in series go out when one is removed, while lights wired in parallel do not? In May of 2008, Lancor helped assemble an interdisciplinary team including University of Wisconsin-Madison graduate students in physics and Theater and Drama. The show was developed and produced with limited input from the original team to foster creativity and test the limits of the FST model. FST creative team members periodically offered guidance throughout the script development and initial performances.

"The Circuit Show" was presented at the following locations in June and July of 2008: The People Program, a college-prep program run by UW-Madison for children from families that do not typically send children to college; The Madison Children's Museum, once outdoors and once indoors; and Grandparents University, a summer workshop for children and their grandparents run by the UW Alumni Association, two shows. The show was designed to be shorter and simpler than the earlier shows and stressed one major concept, the difference between parallel and serial circuits. Because of its simplicity, it was deemed especially appropriate for younger audiences.

Evaluation of "The Circuit Show"

The presentation that was held outside at the Madison Children's Museum coincided with the Madison Farmer's market and was in direct competition with other child-friendly activities. The show was unable to attract a sizable audience. Three children watched the show and were attentive throughout, but the experience revealed the difficulties inherent in outdoor performances in competition with other programs, and particularly highlighted the problems posed by wind and bright sunlight and the need for effective sound amplification.

Method

For this evaluation, knowledge/comprehension was assessed in a questionnaire that included three concept questions. For the People Program and the Madison Children's Museum,

this assessment was after-only; for Grandparents University, a before-after assessment was used. An after-only questionnaire shortened from the one that was used for "The Boiling Point" was employed to assess engagement/interest and attitudes toward science. At Grandparents University, grandparents filled out an after-only questionnaire. Sixty-three children filled out the engagement/attitude questionnaires (54% were boys). Respondents ranged in age from 3 to 14 (Median age = 9.5). The concept questionnaires were filled out by 52 children (28 of these filled out this questionnaire both before and after the show). Twenty-four grandparents returned questionnaires.

Results

Engagement/Interest. Although the show was appreciated overall, age was a critical factor, with the show succeeding most strongly with younger groups of children. The data presented here divide children into two age groups, 11 and younger vs. 12 and older (Figure 8).

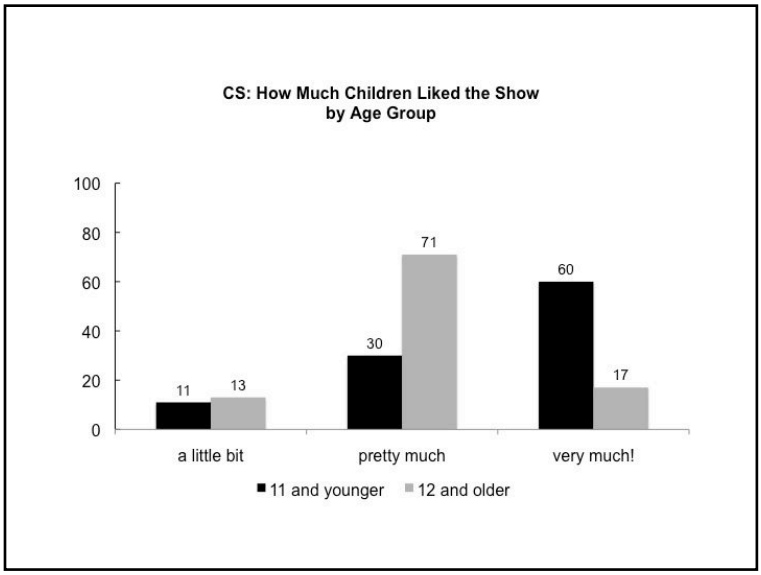

Figure 8. "The Circuit Show": Engagement/Interest

A strong majority of children in the younger group said they liked the show "very much!" and would like to see more shows. Grandparents gave generally positive ratings, but those accompanying younger children gave much more enthusiastic ratings of the show. For example, 66% of grandparents accompanying children under the age of 12 said the show was "extremely" valuable, vs. 33% of those accompanying older children. Children's comments were generally positive (e.g., "it was awesome! ☺," "it was great! I learned a lot"), but some older children recognized that the show was more appropriate for younger children (e.g., "It was good, just it was for younger kids"; see Appendix F). Comments from the grandparents were highly favorable. (See Appendix G).

Knowledge/Comprehension. Knowledge was assessed using three questions. Two showed circuit diagrams and asked, for series and parallel circuits, respectively, what happens when one light bulb goes out. The third question asked a practical application question regarding what type of circuits are likely to be in their living room. (This knowledge test is shown in Figure 9.)

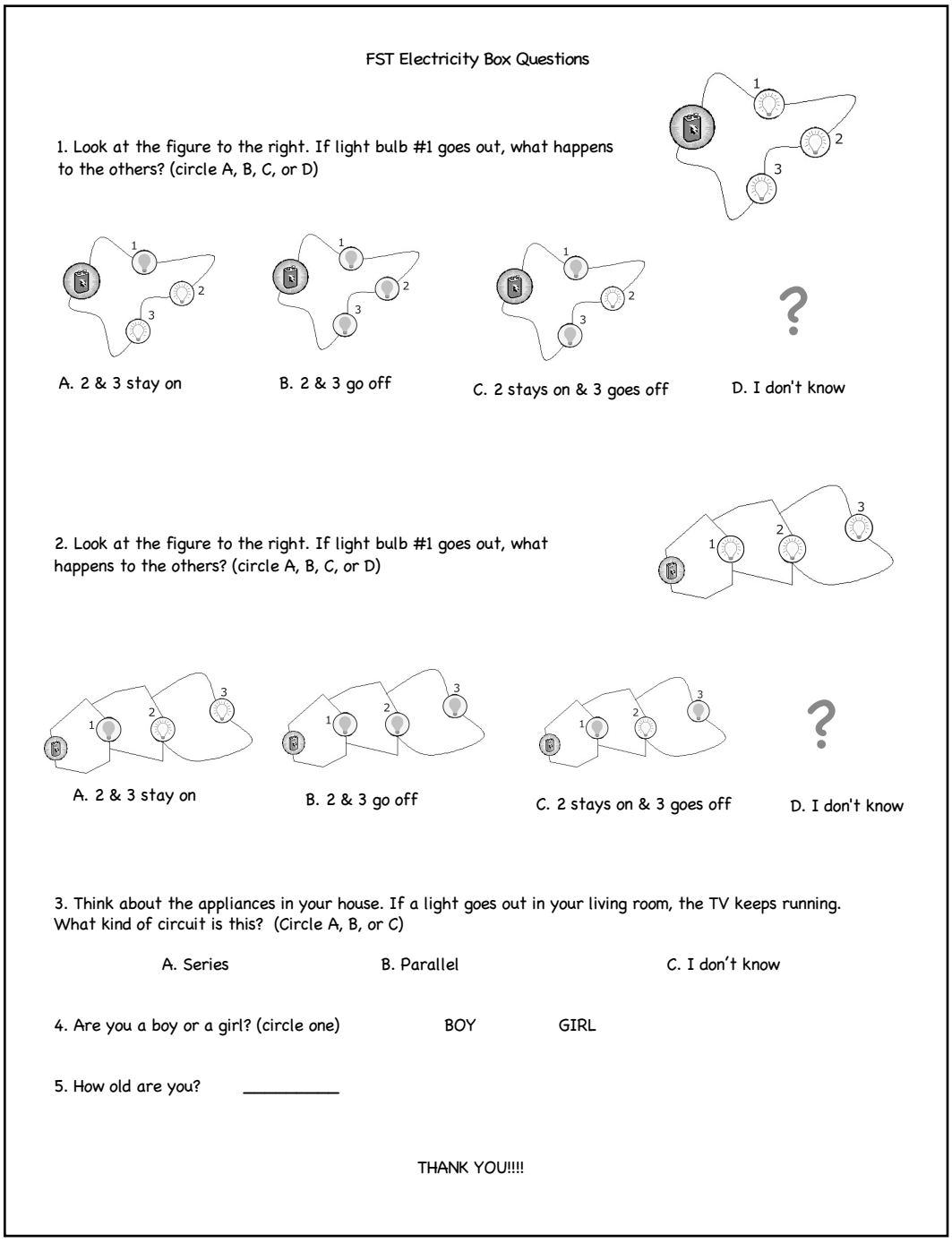

Figure 9. "The Circuit Show" Knowledge Test

Between 84% and 91% of the children attending each session answered these questions correctly after seeing the show. However, the after-only assessment does not indicate how many could have answered these questions before the show. The analysis based on children who answered these questions both before and after the show indicates that significant learning occurred from before to after (Figure 10). [The high "before" rate of correct responding for the Parallel question may be due to the fact that the typical child who knows nothing about circuits thinks lights will stay on (which was the correct answer) based on their experience.]

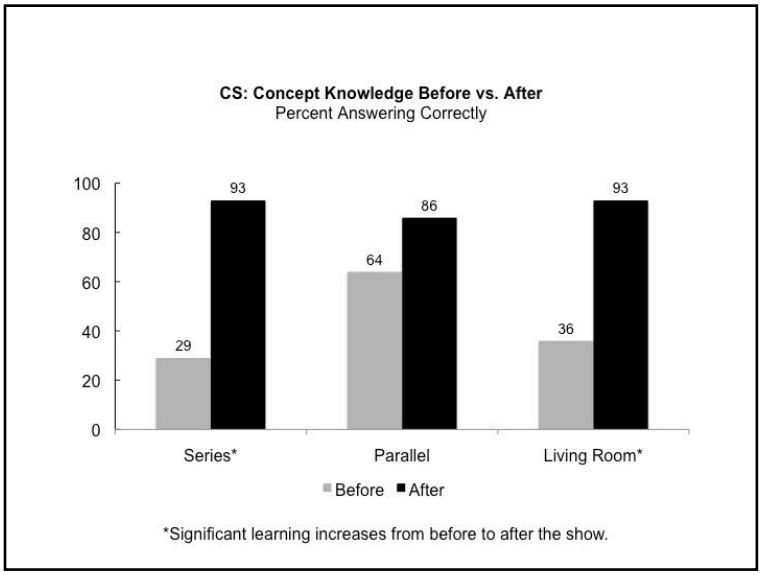

Figure 10. Concept Knowledge Before vs. After "The Circuit Show"

Attitudes toward science. The three statements assessing children's perceptions of the effect of the show on their attitudes toward science were "The show made science easier to understand," "The show made me want to learn more science" (Figure 11) and "It showed me that science can solve everyday problems." These data again showed that the ratings of younger children were highly positive and far exceeded those of older children.

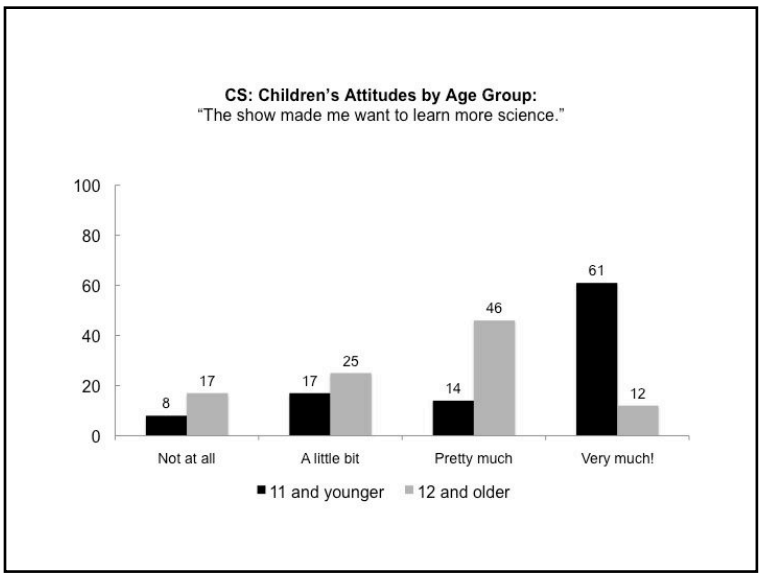

Figure 11. "The Circuit Show": Attitudes toward Science by Age Group

Conclusion

Especially in the 11-and-under age range, "The Circuit Show" produced high engagement/ interest, significant knowledge gains, and increased positive attitudes toward science. It will be recalled that the initial target audience of FST shows was age 4 to 11; moreover, "The Circuit Show" was designed to be shorter and simpler than the earlier shows and thus especially appropriate for younger audiences.

Discoveries and Lessons Learned

The team that developed "The Circuit Show" recognized the value of forming a clear and concise Investigation Question to use as a foundation for the rest of the show. They enjoyed working in an interdisciplinary team. They also learned about the challenges of performing in busy outdoor venues and the need to adapt the scripts to suit the performance environment.

In the end, the FST team concluded that training a team to create their own SI Show involved a steep learning curve for all parties involved. In the meantime, demand for performances of existing shows continued to rise. As a result, they reassessed their strategy to transfer the concept and decided to shift their focus away from training other groups to write their own shows and toward teaching others to perform the shows the team had already created. They developed a training program to teach science undergraduates how to perform "The Boiling Point."

B. Training Members of Students Participating in Chemical Education to Perform "The Boiling Point"

To meet the growing demand for performances of both "The Boiling Point" and "The Circuit Show," the FST team worked with the Students Participating In Chemical Education (SPICE) at UW-Madison. This group was chosen because they had experience performing traditional demonstration shows in the local community. Given their background as science majors, they were also immediately comfortable explaining the scientific concepts introduced during the interactive portions of the performance.

In November 2008, the FST team conducted an all-day training workshop for SPICE and other interested professionals. The morning session introduced FST principles and methods, and demonstrated several elements of performance. The morning culminated in a public performance of "The Boiling Point" by FST staff before an audience of children. In the afternoon, workshop attendees broke into teams and performed parts of the show, followed by feedback.

The workshop was favorably evaluated by the attendees, who expressed high satisfaction with the training, enthusiasm for their future involvement with Fusion Science Theater, and increased comfort with the idea of performing in science theater. The parts they found the most valuable were viewing the live show and then rehearsing parts of it themselves.

The SPICE group then had eight rehearsals in January of 2009. The FST creative team provided materials and support during this time, including a script and video of a prior show, lists of props and supplies, music and sounds, and a prototype of the ballots. In addition, members of FST gave feedback and assistance as needed. SPICE went on to perform "The Boiling Point" 11 times between February and August of 2009. The SPICE advisor, Brittland DeKorver, provided an evaluation of the learning gains, which showed increases in concept understanding in children ranging from 3 to 12 years. She also administered a retrospective questionnaire to the SPICE members who had been involved in presenting "The Boiling Point." This survey showed that participation in "The Boiling Point" was a positive experience for them and changed the way they viewed science education (See Appendix H for DeKorver's evaluation of SPICE activities).

Discoveries and Lessons Learned:

Impact on children and on emerging scientists. The work with the SPICE students had two primary goals: first, to serve children by meeting the growing demand for SI Show performances, and second, to prove that the model was transferable. Both goals were met, and an unexpected benefit also emerged. Just as the children who watched "The Boiling Point" became engaged in science learning in a new way, the college students who performed the show acquired a new appreciation for science teaching.

Identification of potential adopters. Through working with SPICE, FST staff identified a group of faculty and students across the nation interested in performing FST shows in their own

communities: Undergraduate Affiliate chapters from the American Chemical Society. These groups are ideal candidates to perform FST shows for the following reasons: (a) they already have an organization to publicize shows and handle logistics; (b) their previous experience with outreach makes them familiar with demonstrations and comfortable doing activities for kids; (c) they are looking for teaching, outreach and professional development opportunities; (d) they have flexible schedules for rehearsal, prop development, and performance; and (e) they receive a positive teaching experience that encourages them to consider teaching as a career. Because of these benefits, the FST team spent considerable time developing a partnership with ACS as described in the following secion.

4. Disseminating Information about FST to Potential Future Adopters

A. Presentations at Professional Meetings

The Fusion Science Theater team has participated in regional and national meetings convened by a variety of organizations including the Wisconsin Society of Science Teachers and the Graduate School of the City University of New York. Because their most concerted efforts have been through the American Chemical Society, these activities are reported in this section. Other similar activities are reported in Appendix I.

American Chemical Society, Spring 2008, New Orleans

In order to begin networking with like-minded individuals in the field, Kerby and FST-team member Christopher Babiarz organized a special session entitled “Using the Arts to Teach Chemistry” for the Spring 2008 ACS meeting. The symposium showcased innovative practices for using the arts in both classroom and outreach activities. The symposium also explored the potential for the arts to increase engagement in and understanding of chemistry in diverse populations. FST made many connections through this symposium, and their work was later featured in an article that appeared in *Chemical & Engineering News* (see Media Coverage, below).

American Chemical Society, Fall 2009, Washington, D.C.

The ACS Division of Chemical Education was awarded a $7,000 Innovative Programming Grant to bring FST to the Fall 2009 meeting. The three major goals of the presentations were: (1) to demonstrate FST principles to a broad cross-section of ACS conferees through performances and discussions at conference events; (2) to increase public recognition of ACS through outreach activities to under-represented communities in the Washington D.C. area; and (3) to teach educators and students to use FST principles by holding a workshop within the Division of Chemical Education.

These goals were met with two public performances of "The Boiling Point" and several informational sessions within the conference. Each session targeted a strategic audience, based on the recognition of FST as a vehicle for service-learning and outreach:

Chemical Education Professionals: FST presented two posters and screened two videos during a 4-hour divisional poster session. The major outcome from this event was the opportunity to network with elected Division of Chemical Education officials and interested conferees.

College Students: ACS provides special programming during each national meeting to meet the needs of undergraduate student chapters. At one such session, SPICE members Brittland DeKorver and Sarah Schmid performed "The Boiling Point," and Kerby led a discussion with the undergraduates in attendance.

High School Teachers: FST participated in a symposium entitled "Bridging the Gap: Building Collaborations with High School Chemistry Clubs. FST gave a multi-media presentation that illustrated the key principles of FST in the context of a mini-performance of "The Boiling Point."

Public Audiences: FST performed "The Boiling Point" in two D.C.-area libraries: the Martin Luther King Public Library and the Takoma Park Library in Takoma Park, Maryland.

American Chemical Society Spring 2010, San Francisco

FST's partnership with the ACS expanded to include two workshops at their Spring 2010 National Meeting, "Making Demos Matter" and "Creating Demo Shows that Teach and Inspire." During both workshops, members from SPICE provided leadership and peer-to-peer mentoring. A new instructional video that highlights the key concepts of the FST model was created for these workshops.

Making Demos Matter. FST was featured on the Undergraduate Program to discuss their techniques for the use of demonstrations to serve a purpose beyond simple spectacle—namely, to meet a predetermined learning-objective that can be woven into demonstration shows. Approximately 200 undergraduates attended this workshop. To gauge interest in following up with the FST approach, the presenters distributed evaluation forms that included the following four statements and solicited respondents' degree of agreement or disagreement: "I would like my organization's demonstration shows to be more learning-centered," "I would like to perform a show from a script that Fusion Science Theater developed," "I would like to use Fusion Science Theater methods or template to develop our own outreach show," and "I would like to attend another workshop that will teach me more about Fusion Science Theater techniques and how to use them to develop an outreach show." Questionnaires from 57 of the attendees were received.

The responses indicated strong interest in what the FST approach has to offer: 100% of respondents agreed they would like their demonstrations to be more learning-centered; 56% said they would like to perform FST scripts; 78% said they would like to use FST methods in their own shows; and 68% said that they would like to attend more workshops.

Creating Demo Shows That Teach and Inspire. This smaller workshop, which was designed to help people reverse-engineer better outcomes to their existing demonstration shows, was attended by 25 undergraduates and their faculty advisors. The same evaluation questionnaire was administered, and 21 questionnaires were received.

These responses were also highly favorable: 81% agreed they would like their demonstrations to be more learning-centered; 62% said they would like to perform FST scripts; 76% said they would like to use FST methods in their own shows; and 67% indicated that they would like to attend more workshops.

Attendees at both workshops gave written comments that will be helpful in designing future workshops. Several of the participating groups from the second workshop have signed on to be partners in FST's upcoming full-scale proposal to train undergraduate science majors to perform Fusion Science Theater shows.

(See Appendix I for a full list of FST presentations at meetings.)

B. Publications and Media Exposure

Media Coverage of Fusion Science Theater

Fusion Science Theater has received substantial positive publicity. Their press and media appearances are as follows:

"Using Street Theater to Channel the Lesson of Molecules" by Terry Devitt, *University of Wisconsin-Madison News,* April 7, 2008 at http://www.news.wisc.edu/15019; also featured on many other web-based news services.

Interview of Babiarz and Kerby on Fusion Science Theater's Science-in-a-Box on Madison radio station WORT on April 18, 2008. This interview is available on the Fusion Science Theater website at www.fusionsciencetheater.org.

Fusion Science Theater principles, shows, and evaluation methods were featured in an article titled, "The Lure of Informal Education" in *Chemical & Engineering News*, November 24, 2008, pp. 45-48. A photo of a "Boiling Point" show was included in this national publication of ACS.

An interview of Kerby discussing the work and success of Fusion Science Theater was featured in the *Wooster Alumni Magazine*, Fall 2010.

Kerby was featured in "Work: Live & Learn" in *Brava Magazine*, August 2009, pp. 29-20.

Articles by Fusion Science Theater Participants

Kerby, H. W., Cantor, J., Weiland, M., Babiarz, C., & Kerby, A. W. (2010). Fusion Science Theater presents *The Amazing Chemical Circus*: A new model of outreach that uses theater to engage children in learning. *Journal of Chemical Education, 87* (10), 1024-1030.

This is the first peer-reviewed paper to appear. It was a featured article, with images from "The Amazing Chemical Circus" on the cover of the journal. The article describes the development of the Circus, the challenges and advantages of cross-disciplinary efforts, and the many discoveries made along the way. In particular, the use of theater-in-education techniques to create a participatory, inquiry-based, multi-model learning experience is discussed. It also presents the data on children's engagement/ interest, knowledge/comprehension, and attitudes toward science that are included in this Report.

Other publications:

Babiarz and Kerby published an article entitled "Undergraduate Science Majors Take the Stage in Science Investigation Shows." Fall 2010 edition of *IMTAL Insights* (International Museum Theater Alliance).

DeKorver published an article entitled "Doing More with Chem Demos" in the September/October issue of *InChemistry*, the bimonthly newsletter for undergraduate affiliates of ACS.

C. Internet Presence

Fusion Science Theater Website

The Fusion Science Theater website (www.fusionsciencetheater.org) was designed by graphic artist Candace Gallant and launched by webmaster Joyce Johnston in January 2008. This site provides basic information about the project and productions in addition to educational materials for children and links to film clips and a radio broadcast about the project. The site was redesigned in 2009 to match the graphics of the Fusion Science Theater logo and brochure. Content about SPICE performances and training opportunities was also added.

In June the website content was expanded to include the promotional videos created by Rob Matsushita (August 2009) and Marcy Weiland (March 2010). The videos were originally produced for the group's work at the American Chemical Society's National Meetings in Washington, D.C. and San Francisco. Weiland also edited and posted a video sent to us by San Francisco workshop participants from Sewanee University, TN.

Fusion Science Theater Facebook Page

FST staff launched a Facebook page in July 2009 to help advertise the public performances of "The Boiling Point" in Washington, D.C. In April 2010, Brittland DeKorver reinvigorated the FST Facebook page by actively managing the content. As a result, membership on the page dramatically increased to more than 70 from an initial count of 8. Page views also increased substantially as a result of her efforts to regularly update the content and spark discussion.

Summary and Conclusions

The Fusion Science Theater Planning Grant met and exceeded the goals it set out to pursue. To develop and evaluate the FST model, it presented three different Science Investigation Shows. The first, "The Amazing Chemical Circus," was revised from its previous showing to incorporate lessons learned from its initial production, specifically, focusing each "ring" of the circus on one specific educational objective. The second, "The Boiling Point," was a shorter, more portable show that explored the molecular-level interactions underlying water vaporization. The third, still shorter presentation, "The Circuit Show," investigated the difference between serial and parallel circuits.

Each of these shows teaches by posing an intriguing, dramatic question that the audience investigates using the steps of the scientific method. Children consider various hypotheses, observe demonstrations to gather data, participate in a kinesthetic model of the fundamental concepts, predict results, and discover answers in the show's climax. Characters engage audience participation via Q & A, sing-a-longs, the use of humor, and physical dramatizations.

The performances of all three shows were evaluated on a variety of fronts. First and foremost, children's reactions were assessed in terms of their engagement/interest, their knowledge/comprehension, and the impact of the show on their attitudes toward science. All three shows demonstrated enormous success in all three domains. In terms of engagement/ interest, the majority of children gave the shows the highest possible rating and expressed interest in seeing more shows like them. (See Figures 1, 5, and 8.) Beyond these numerical ratings, children's comments in their own words conveyed the enthusiasm and fascination that characterized their responses. (See Appendices A, C, and F.) In addition, parents, grandparents, and educators were extremely enthusiastic about the shows and their impact on children. (See Appendices B, D, E, and G.) All three shows provided evidence that they improved children's attitudes toward science. And in one of the most novel aspect of informal science education, all

three shows demonstrated significant increases in students' learning of important scientific concepts from before to after the show. (See Figures 3, 7, and 10.)

The project fulfilled the second goal, to transfer the model to others, in two ways. First, the third show, "The Circuit Show," was developed and performed by an outside group—members of The Wonders of Physics at the University of Wisconsin-Madison, under the guidance and mentoring of project staff. Second, FST staff trained SPICE, a group of Chemistry undergraduates at UW-Madison to perform "The Boiling Point" before a variety of audiences. Evaluations showed that the transfer was highly successful. Children enjoyed and learned from these shows, and participation in these performances had a positive effect on college students' attitudes toward teaching science.

Project staff met the third goal, to disseminate the FST model to potential future adopters, by attending conferences, and by producing publications, attracting media coverage, and establishing a presence on the Internet. They participated in many highly successful presentations at professional meetings, most notably at three national meetings of the American Chemical Society. At these meetings, FST staff presented numerous talks, workshops, and public presentations to a variety of audiences. These presentations were well attended and very well received, and succeeded in lining up many supporters as well as recruiting students for participation in future FST endeavors.

The FST team and its efforts have received substantial positive media coverage. They have also successfully published their first peer-reviewed paper, which appeared as a featured cover-story article in the *Journal of Chemical Education,* and they are working on more academic publications. They have also created and maintained an informative web site that serves children as well as potential collaborators, and have begun using Facebook to communicate with various interested groups.

In summary, this Planning Grant has demonstrated that the Fusion Science Theater model works. It successfully uses the dramatic structure of a play to create an investigative, participatory theater event that conveys science information, concepts, and methodology in a way that is engaging to children and attractive to parents and educators. The model can be transferred to others both by teaching others to develop their own shows and by training undergraduates to perform FST shows that have already been created. Finally, significant achievements have occurred in publicizing the model and in recruiting others to join in learning and using it. For these reasons, the FST approach makes a significant contribution to the field of Informal Science Education as it infuses the discipline with new products, methods, and practitioners.

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Appendix A:
Comments Made by Children on "The Amazing Chemical Circus"*

Youngest Boys (2-5):

Very fun Very Very Very Cool

Great! nice!

Youngest Girls (2-5):

(From parent) "It scared her."

Really liked it!

Yes, I enjoyed the show.

Middle Boys (5.5-7):

A lot, very much, thank you for the show.

I liked it a lot

I loved the show

It was great!

Too long. I liked in between pretty much & very much.

Middle Girls (5.5-7):

I thought it was very good ☺

I was very scared of the fire.

My favorite part were the balloons and the big tube explosion

The scientists were great

Want to come again

Oldest Boys (7.5-14):

I liked it a lot ☺

I really liked it!

It was awesome!!!!!!!!!!!!!!!!!!!!!!

Exciting!

Oldest Girls (7.5-14):

That was amazing

[*NOTE: In this and the other Appendices, spelling errors have been corrected, and punctuation has been added for clarity.]

Appendix B:
Comments Made by Parents on "The Amazing Chemical Circus"

ID	What do you think are the strengths of this science theater show?
100	Relating science to daily experience
101	Use of humor, a narrative script.
102	You really know how to talk and interact with children
103	Involving kids
104	All, fun, and facts
105	It can light the children's interest to science
107	Act it out I thought was very important
108	Demonstrations
109	Personality
110	Everything
111	Catered towards all ages
112	Having a female scientist
113	Science is fun
114	Science is fun
115	Entertaining & informative
116	Helps kids to understand science
117	The experiments made it real & easier to understand for the visual learner
118	The explosions
119	To encourage kids to learn about chemical science and explain how science works
120	Visual representations of concepts
121	The act-it-out brings it to their level
122	Engaging and funny – Right length. Scientists good @ using simple terms
123	Acting it out helps a lot. Showing how things work. I thought it was great
124	Very interactive
125	Good, basic and easy concepts. Visuals aid a lot
127	Interactive, length, high energy
128	It presented information in creative, engaging way
129	Fun Drama, explosions
130	Lots of energy
131	Science at work
132	Fun way to learn!

133 Fun, easy to understand, getting kids involved

134 The teaching so even the children understood

135 Engagement; entertainment; repetition; focusing on a few important points so that we can remember better

136 Entertaining; "act it out" parts

137 It seemed very entertaining for the young audience. It kept their attention

138 Combo of hands on, cool examples & silliness

139 Features science; makes it fun; appeals to a wide variety of ages 3-9

140 Very fun; made sense of complicated topics

141 Engaging real experiments/ drama

142 Kept kid's interest with silly Squirt and Ringmaster. Clear demonstration of concepts. Audience participation

143 FUN!

144 Very exciting! Common substances. Engaged kids. Females and male actors/ scientists

145 Exciting demonstrations. active participation

What could we do to improve the show?

100 Explain terms like atoms, hydrogen, oxygen. What does it mean to say they're invisible but we know they exist?

102 Warn people during the combustion part that they all make noise, she got very scared.

103 Nothing

104 Nothing I saw

105 Add more magic things

107 Larger room/more hands on (volunteer) experiments

108 It seemed to be fine

109 More experiments

110 More, longer

111 More on stage involvement

112 Answer questions – why can't you touch the polymer for 24 hours, what kind of chemicals were used.

113 Faster pace

114 Start off faster

116 More little gifts & more hands on

117 It's hard to reach such a large range of ages – the "older" kids thought the acting was goofy, but the experiments were cool

119 The show seems to me exciting, would be more frequent.

120 More gimmicks like Bob the Science Guy or a powerpt for wandering eyes and minds to go concurrent with the show

121 Offer a bigger audience seating. Last – Dr. Kaboom – too soft spoken – crowd control

122 Have more. Rotate themes (i.e., experiments)

125 Microphone perhaps

127 Pace a little faster

129 Lasers

130 Ventilation in room! (lots of fumes)

131 It's Great

133 Give out more tickets & perhaps some ventilation

135 The transition to Dr. Ka-Boom was slightly bumpy. We almost got lost. But she did a great job getting the young audience's attention. Maybe Squirt and Ringmaster could help. But you all did a fabulous job keeping our attention. Go out & have ice cream.

137 More Squirt!

138 Scripted actors including youth actors – Squirt has a lot of potential

139 Audience participation is really good; experiments were great

140 More space for more people

142 Better ventilation! Plastics in particular were stinky. Make segments slightly shorter – they dragged on.

143 It was great!

144 The 4 year olds didn't seem to stay focused

145 A little more practice for scientists in relating to kid audience

Please give us any other comments or suggestions you may have.

102 It was great. I loved the models

104 Thank, you for this show. I even had fun

106 It is pretty good

111 It was a great show. Thank you very much ☺

115 Could you list what the demos used so I could do these in my high school classroom.

116 Will be nice if the kids can have hands on.

117 This was great for the kids. The more they can see the more real & interesting science can be. It was nice last year to make slime—hands on opportunities would be good – but I know the culinary event prevented that.

119 Thanks/We appreciate your interest to help us to understand better science

120 Thank you!

121 Thank you!

122 Thank you --

126 Excellent

127 Great job!

129 Loved it!

131 Wonderful entertainment

132 Thank you!

133 Thank You!

134 I enjoyed the show.

135 I can see some after performance packets with information to help retain the learning and extend it into their lives.

140 Great Show!

142 Give more cues for verbal audience participation, like counting out spoonfuls of powder for diaper demo

144 Thank you! Great fun!

145 Thanks!

Appendix C: Comments Made by Children on "The Boiling Point"

I like it. It's funny, fun, and we learn from it, and I love science. It's my favorite subject.

I thought that it was excellent. I like science sometimes.

I thought the show was really cool!!

I loved the show very much!! My favorite part was when you acted out the tea pot and molecules!! I also liked the part about the balloon!!

It was awesome. I wish I could see you guys again.

I loved it, it was awesome!

It was funny and cool and very scientific.

I thought that the show is great for learning about science. I thought Watch and Wonder were really funny

I love the show

I liked it. I think it was fun

I would like to see the flame.

I liked when the others got to act out the molecules. I liked that we got to learn science in a fun way. I learned that parts can be acted out parts and it can make you look at science in real life not just through books.

I liked when you guys did the can when it got sucked in. I learned that when the water boils it.

I learned that H_2O is a molecule. I liked the experiments

I really like how some of the kids acted H_2O. That was really fun. We learned how water boils and it was really how the can collapsing and we what would happen to a balloon in a teapot.

1. The show was silly because Wonder played that gold whistle. 2. The H_2O dance was funny because the people had to dance and the music was funny too.

It was very good. It taught me about H_20.

I thought it was great. I loved it. I learned what _?__ what _?__ molecule was. Great show [nice diagram of teapot on back]

I liked it because it was very funny and different. I would like to have more time with the acting out. Thanks for listening what I have to say.

I thought that it was fun and I might be a scientist when I grow up. I also learned about water molecules and H_2O.

I loved everything. I learned a lot about what water does when it boils.

I learned the part about the collapsing can.

The show was funny. I'm looking forward to another one.

I really liked the show. It taught me lots of things like molecules and more stuff about atoms. I like how you are funny and have the songs that help us remember them. I think kids will love them (acts+Watch+Wonder)

I liked the parts when the can collapsed and the part when the balloon went into the pot and I thought it was very well thought out.

I like the act. I learned you can put a balloon in a coffee pot. That was cool.

I learned that the balloon went inside of the teapot. I liked it when the tin sucked in.

I learned about molecules and how the two "H's" and the "O." I liked it when the balloon went inside the pot. I also liked it when some kids got to go up and be water molecules.

I loved the boiling part, the molecule part. I learned that it takes a while to boil.

I love it!!

I liked the show but most of all the experiments.

I loved it. It was awesome. I want to be a scientist too!

It was pretty good. I think the 2nd graders would love it. Thank you.

I like the part that you boiled the can and it shrank.

I loved the show. I loved the girl playing the kazoo

It was awesome. I liked the experiments a lot. They were cool. I would love to see another show.

I liked the show. I also liked your song. It was very cool. I liked how Wonder would play her instrument while one person was talking. It was funning but learning

It was ok. Not the best show I ever saw but it was interesting.

It was real funny.

I thought it was pretty cool. It was a fun way to learn some science!! Science is my favorite subject!!

It was pretty good but I wish the fire actually lighted.

It was fun to hear all about those things and seeing the can crumble. The whole show was cool.

It was cool, and I loved how you made it funny and science at the same time. I liked how she brought the kazoo out. Please come again. P.S. Soooooon?

It was really funny and cool. I am going to try some of the experiments at home.

It was okay for the most part. The collapsing can was pretty cool. I liked it when the balloon turned inside out.

It was very good. I learned some things that I did not know.

I loved it. It was awesome. It was fun and scientific.

I thought it was pretty cool especially when you acted like high schoolers. It felt pretty weird for a fourth grader.

It is the greatest science show in the history of science shows.

I loved it! I learned a lot, while I was having fun!

It was a good and fun show.

Appendix D: Comments Made by Parents on "The Boiling Point"

ID	What do you think are the strengths of this science theater show?
40	Actors & set-up
41	Engages the kids and allows participation
42	Very kid friendly; very interesting for grown-ups; easy to understand
43	Creativity through teaching; children involvement; give ? for children to think about
44	Format completely engaged children
45	Very illustrative
46	Good engagement, good visualization
47	Demonstration – visualizing
48	Active, visual experiment
49	Can crushing experiment was fun for kids; explanation of scientific method
50	Good demos; friendly presenter; good info
51	Scientific method made fun; kinesthetic
52	Very entertaining which made the learning fun.
53	Staff
54	Get kids up and involved
55	This was <u>great</u> for elementary-aged kids. Very interactive & Fun!! Very original (loved your songs)
56	Funny, cool; definitely had the kids engaged
57	It's very entertaining and explains science in a simple way children can understand
58	Age appropriate. Includes audience. Uses humor.
59	Funny. Emphasis on hypothesis and experiment
60	Creativity, educational; fun; interactive; short ½ hour
61	The experiments, the box, & the interactives were cool.
63	Interactive and fun and clear – This is how science should be !! ☺
64	Easy to understand; visual; participatory
65	Geared to lower grades than my son (12 years old), but did a good job giving a simple explanation
66	Singing, kids participating
68	The entertainment & box as a way to teach the concepts
69	It becomes a learning experiment that is fun.
70	Bring science to life

71 Kinetic learning; length appropriate; focus on one concept

72 Total engagement of the children's attention! Hands on, involvement, visual; Awesome

73 Good focus; real science presented in fun manner

74 Interaction; hands-on learning; fun ☺

75 Humor, audience interaction, visual

What could we do to improve the show?

40 Boiling & cooling are separate events. I'm not sure that was always clear

42 Nothing

43 Have kids read what the four options are

44 More experiments

49 Overall flow of performance; interaction between performers and performers w/ box

50 Introduce the box earlier (as a concept)

51 More of them

52 A different venue would help for better hearing

56 Great performing but more box please

58 A touch more info about strong bonds between H & O

59 Don't forget the "don't do this at home" warning when you stick your hand in the steam from the kettle. Steam burns can be nasty if not from kettles, then from rice steamer.

61 Tie each experiment back to the theories more directly.

65 Have a bigger room with more chairs for adults to sit down

68 The balloting was pretty distracting

69 Have it in a larger space that is air-conditioned

71 Give recommended age for show in program literature; more time on set-up – explaining teapot boiling

72 Not sure, it's so good the way it is. I'd have to think about it.

74 Bigger space, more chairs

75 A bit faster paced to hold younger audience attention. Show of hands to ballot would have been much quicker

Please give us any other comments or suggestions you may have.

40 When you ask the big questions make certain they carefully asked if you hope to get good answers.

43 The music was a great touch

45 Great show

46 Maybe the water molecules get bigger when they get hot

51 Have you thought about hiring yourself for birthday parties?

56 This was great, guys. I'm scared of science and I really enjoyed myself. There were some rowdy boy scouts who kept me from hearing some of it. Like to see you in a different venue.

58 Thanks!

59 Sparkling water comes in cans. Soda is not needed. We did just this experiment with sparkling water cans at home.

60 This was great, thanks!

63 Great show! I learned something about chemistry & my kids can understand it, too.

66 Great job!

67 Great show, especially for younger kids!

68 Let the kids hold up something to vote

74 Love this whole event. Please keep doing it. ☺ Thank you!

Appendix E: Comments Made by Educators on "The Boiling Point"

ID	**What do you think are the strengths of this science theater show?**
1	Science info taught through demonstration and humor.
2	Showed the process of scientific thought in a way that kept the kids riveted and parents with a smile on their faces – Great audience involvement
3	Interaction with audience; singing show master was great; scientist was great – funny and informative
4	It was actively engaging. Children were encouraged to draw conclusions. They have follow-up activities.
5	Great demonstrations. I really liked the "human" model of molecules – excellent idea I like the orange balloon & the orange belt; helped kids visual better
6	Lots of visuals! Hands-on activities! You got students involved! You did a nice job of making atoms & molecules come alive!
7	Enthusiasm, kinesthetic aspects, scientific method
10	Having the kids vote before and after—to see if they change their minds. and document how much.
11	Funny, engaging, well-scripted
12	Use of science terms; participation; doing voting twice to see change as a result of experiment.
13	Great use of demonstrations and activities. Very engaging
14	Children's participation – ballots are great idea; water molecule movement with children; human with glasses to learn safety; explanation and references to mode; Each step of experiment process has examples

	What could we do to improve the show?
2	• Move your audience closer • Make the box so that the doors close • Can you get the gallon can up and visible for your audience to see it collapse? It is not easy to see the process in the tub
5	Transitions were a little choppy – great ideas & information – I would just work on the overall flow
6	Why the kazoo? It got a little distracting.
7	A bit more learning content to keep things moving along
10	Faster pace.

12	Might want to do 2 votes on one sheet to better understand effects of show; might want to advertise with age-range recommendation
13	1. Safety – teapot should be in center of the table and kids should be 5 to 10 feet away so they don't accidently kick table and knock off pot. 2. Have children explain their predictions for the can. It is the why that is the key. Perhaps have the kids talk to each other about their predictions and then have the groups report their "group" prediction and explanation.
14	Maybe not use the word "implode" with can at end. Let the kids use own descriptive words.

Please give us any other comments or suggestions you may have

1	Such a great way to learn science
2	Wireless microphones might help in a big venue
3	More! More! More!
6	I loved the voting process! That is wonderful!
7	I thought it to be below their maturity level, but afterwards a few of my students said it was hilarious.
10	Great job!
13	Great show! very valuable, engaging, and entertaining.
4	Great job! Fun, engaging and wee? Kids can remember whenever they see water boiling

Appendix F:
Comments Made by Children on "The Circuit Show"

ID	Age	Comment
46	7	It was good!
42	8	It was OK
58	8	It was great!
63	8	I did one of the experiments and it was fun!
40	8.5	It was awesome! ☺
30	9	Crazy (loco)
31	9	I thought it was pretty good
34	9	I thought it was an easier way for kids to think about circuits
43	9	It was funny
59	9	I thought it was a really funny way of expressing science
23	10	I was very good but maybe a little more interacting with the little kids. Great job
38	10	It was very entertaining. I liked it.
39	10	I learned this stuff last year, but it was funny. PS Rachael, he was trying to start the show without you!
2	11	It was too simple. I have straight A's in science and we have done electronics. I knew all you had to say. You should use light emitting diodes, capacitors, potentiometers, resistors, and multimeters. For a younger group, this would be good but for us it is too easy
15	11	It made learning about circuits more interesting than someone talking about it
17	11	It was good, just it was for younger kids
26	11	It was pretty good
35	11	It was great! I learned a lot.
1	12	I think that this show would be very good for a younger audience, as you said. It's informative, but not boring like a lecture or reading from a textbook. I think it can really help kids to understand
4	12	The show was definitely easy to understand. I loved it!
8	12	I thought the show was very funny and understandable for kids of a younger age. I liked how you showed the electrons and light bulbs interacting. It made it easier for me to understand
13	12	It was good not bad not very excellent but it was good
14	12	I thought it was really interesting. It made me understand science more

25	12	It was a very easy way to learn about circuits.
29	12	I learned this when I was in 4th grade and I think it would have helped me a lot
3	12.5	I think when you're with younger kids you can use that voice but with older cut it out because we know you don't really talk like that
7	13	The show was pretty good. The visuals really helped me understand it.
11	13	I liked it because they brought everyday life problems into it and made it funny. They should use 9 volt batteries and L.E.D lights next time
16	13	I thought that it could be a little more for older kids because a lot of us I think already knew the stuff
21	13	Don was funny
24	13	It was an easy way to learn about circuits
27	13	A good way for younger kids to learn about series and parallel circuits
28	13	I thought it would be better for younger kids
5	14	I think the show was good, funny, and understanding for kids. I loved it
6	14	It was really good. I wish they could have shown us shows like that when we were younger
9	14	I think the show was very funny and you can learn a lot about science while standing up and interacting with the actors/actresses
10	14	It was kind of boring b/c it was suited for younger kids.
12	14	I thought it was funny and cool, but I also learned something. Loved it ☺
18	14	The show was good but some of the things that happened like the one light going out could be better if you had two lights go out
19	14	I thought it was a little cheesy but I was able to watch it without being bored
22	14	Considering the show was made for a younger audience it made me feel a little dumb. I think I suggest making another show for older kids
41	14	It refreshed my memory

Appendix G: Comments Made by Grandparents on "The Circuit Show"

Groups with Predominantly Younger Children

ID	What do you think are the strengths of this science theater show?
12	Interaction with others; visual presentation very good
13	Made concept fun and understandable
14	Kids do what they learn. "Doing" is great.
15	Made electricity visible
16	The involvement as part players.
17	It taught the lesson in a way that really held their interest
18	Simple explanation; holds attention
19	Simple explanation
20	You make it interesting & easy to understand
22	Involvement of children; intrigue
23	Good acting; lots of energy; great participation with children
24	Presentation to the age/education of the children

	What could we do to improve the show?
12	Go slower
13	A tiny bit shorter in order for concept to be understood.
14	Nice as is.
15	Rachael's headlight should not shine in my eyes – point it up!
17	Nothing that I can think of.
19	Nothing
22	Super!
24	Presentation to the age/education of the children

	Please give us any other comments or suggestions you may have.
12	I think as much participation as possible is good.
13	I love the show as a learning tool. An excellent method of teaching!
15	You could put a little more effort in showing the parallel lines in the parallel diagram.
19	Good show
23	2 people very patient with their audience

24 As above, the identification of your audience

Groups with Predominantly Older Children

ID **What do you think are the strengths of this science theater show?**

1 Creative demonstration of concepts
2 Basic principles – made simple to understand science
3 The demo's were very clear and easy to understand
4 Shows the difference between parallel and series circuits and application to real life
5 The visuals were well done! The presenters were great.
6 Keeping interest
7 High potential
8 Mystery – acting – involvement
9 Keeps their attention
10 Good visual representation of concepts; humor; class participation

What could we do to improve the show?

1 Don't have any ideas
2 Flashy and larger props
3 It was fine with me
4 Possibly slow down; mention something about x-mas light strings
5 Include a method to make it more age-related.
6 Explain that you need one parallel line for <u>each</u> bulb/appliance, i.e., 1:1 ratio
7 Define age groups.
10 "Signs" bigger to be seen at back of room. Give blue "test" before and after show.

Please give us any other comments or suggestions you may have.

2 I think that it is a good learning tool.
3 Use more commonplace examples of parallel and series circuits.
4 Keep up the good work. Young people this age have good retention and benefit greatly.
6 Nicely done.
9 Involvement of the students was great
11 Spend time to see the museum in this building.

Appendix H:
Evaluation of Fusion Science Theater's "The Boiling Point"
as Performed by *Students Participating in Chemical Education* (SPICE)
by Brittland DeKorver

The Boiling Point

Members of SPICE participated in a day-long workshop hosted by Fusion Science Theater in November, 2008. Subsequently, SPICE planned and ran rehearsals independently of Fusion Science Theater and developed a set, props, and costumes for "The Boiling Point." From February to August, 2009, eleven shows were performed at seven venues. The dates and locations are listed below. One performance was given unless otherwise noted.

Pinney Branch Library, Madison, WI; 02-07-09
University of Wisconsin-Madison, Madison, WI; 04-04-09; 4 performances
Meadowridge Branch Library, Madison, WI; 04-18-09
Science Fair at Oregon Elementary, Madison, WI; 05-02-09; 2 performances
Madison Children's Museum, Madison, WI; 05-04-09
Westminster Presbyterian Church, Madison, WI; 05-18-09
La Petite Academy; Waunakee, WI; 08-07-09

Audience Response

Knowledge/Comprehension assessment was integrated into the show. Paper "ballots" were distributed to children before the show. Children "voted" for the answer they considered to be correct by filling out the ballots before and after investigation of the learning objective. The ballots were collected immediately after each vote was held. For children who were not proficient in reading and writing, parents were asked to assist their children by reading the questions and filling in the child's answers. 231 pre-investigation ballots and 187 post-investigation ballots were collected from children. Respondents ranged in age from 3 to 12 years. 52% of respondents were boys.

Knowledge/Comprehension Results

The questionnaire contained one concept question, asking what happens to the molecules of water when it boils (Figure 1.) The percentage of children who answered this question correctly increased from before to after the show (Figure 2.)

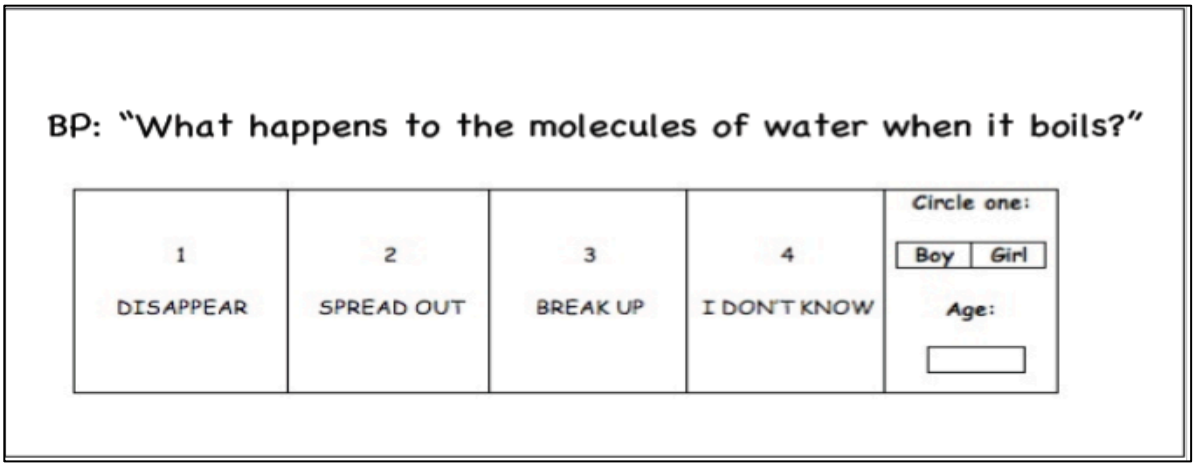

Figure 1. The Knowledge/Comprehension Ballot

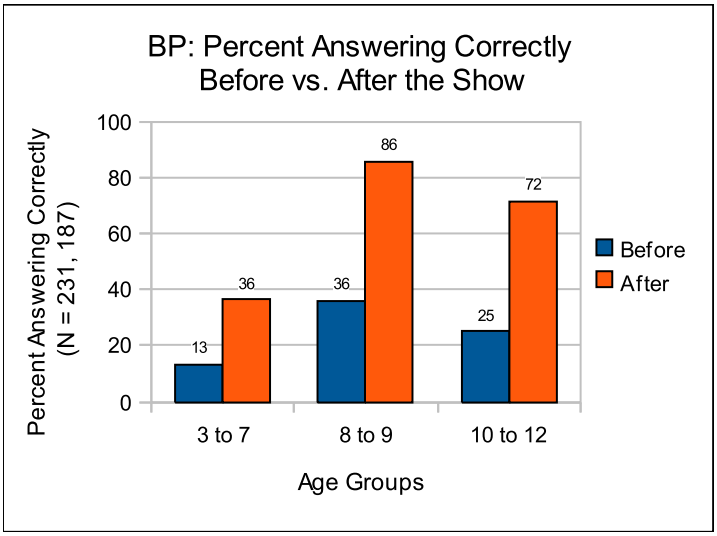

Figure 2. Learning from "The Boiling Point"

Evaluation by SPICE Participants

In May, SPICE members who had participated in the workshop and had worked on the shows were emailed a survey. The survey contained six Likert scale items asking the respondent to rate the impact that their participation in "The Boiling Point" had had on their comprehension of the content and their attitudes about science teaching. The students were given room to explain their choices for the Likert items. Two free-response questions were also included. Seven SPICE members returned the surveys.

Survey Results

SPICE members responded that participation in "The Boiling Point" did not change their understanding of the science concepts, but it did change the way they would explain the concepts (Figure 3). In their open-ended responses (Figure 4), participants said that they felt that "The Boiling Point" was a positive experience for them and for the audience.

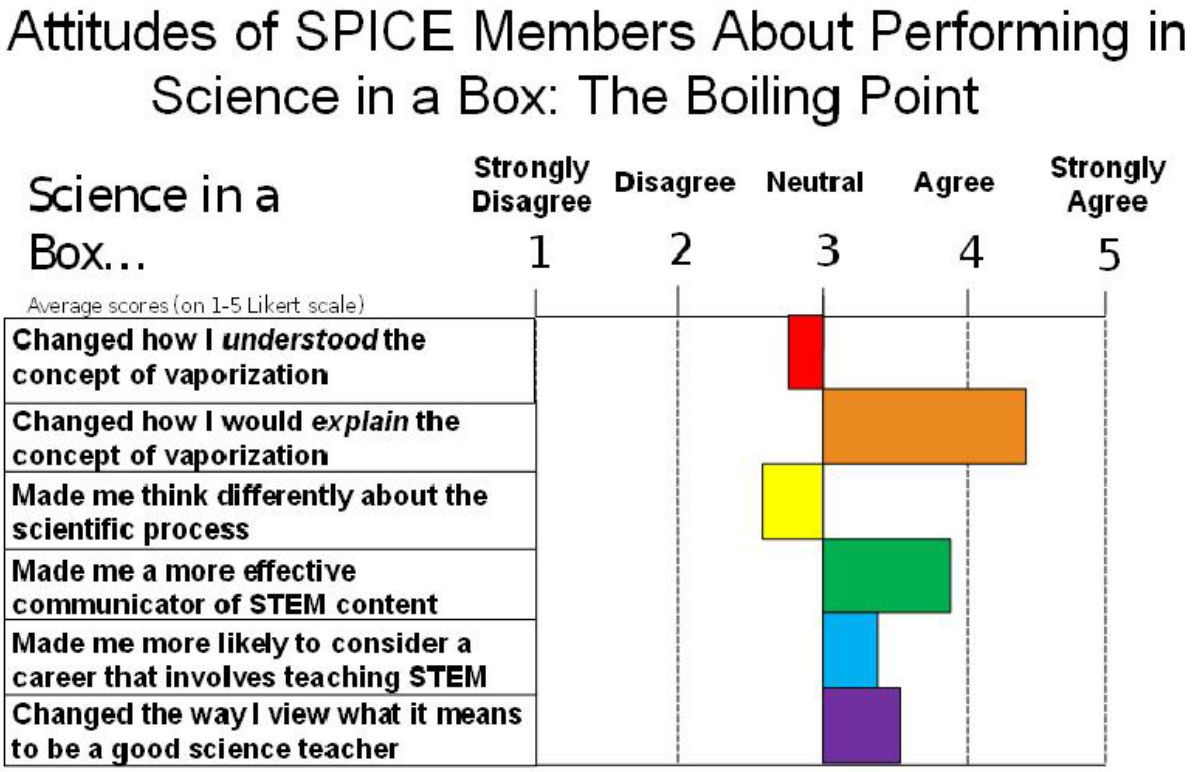

Figure 3: Student Responses on Likert Items

Conclusion

"The Boiling Point" as performed by SPICE did extremely well in increasing science knowledge/comprehension among students aged 3 to 12. SPICE members felt that "The Boiling Point" was an effective tool for informal science education.

Evaluation Conducted by
Brittland DeKorver

Figure 4: Students' Open-Ended Responses on the Benefits of Participating in FST's "The Boiling Point."

Questions:
Did working on "The Boiling Point" change how you understand the concept of vaporization? Did working on "The Boiling Point" change how you would explain the concept of vaporization?

Walking through the scientific method from start to finish made it more fun for the kids, because they were able to discover the answer for themselves and therefore they were more likely to remember it, and made it easier for me to focus on what part of the question confused them. All in all, it was much better than just giving a lecture on the material.

I knew what happens when vaporization occurs, but this gave a much more thorough and complete explanation that is readily understandable to a child. Such as, I knew that when the water molecules gain energy, they spread apart, but I didn't think to explain the other logical options such as breaking apart.

I feel that my understanding of vaporization did not change, but my ability to explain the process improved. The experiments provided the necessary evidence, and the process of working through the hypotheses at the end of the show with the kids forced me to search for better ways to explain why or why not that particular hypothesis fit the data. Also with an interactive show, the actors are forced to adjust from audience to audience. One has to get a feel of the audience each show, and because of this I feel that the boiling point forced me to learn alternative ways to say and explain things. The nice thing about the show is that it takes the kids through the steps of the scientific process, and with a little bit of "coaching" from the scientist, the kids are able to reason through the hypotheses. It is much better than me standing up there and reciting facts, and much more conducive to the learning process.

I learned a correct but simpler way to explain vaporization to younger aged children.

The dance of the water molecules shows children how molecules act when in different states as does the various experiments (balloons and can).

The boiling point show gave me analogies to use in order to better explain vaporization. Also hearing it explained many different ways by different people while they performed the show also showed me new ways to explain the concept.

Questions:
Did working on TBP make you a more effective communicator of STEM content? Did it make you more likely to consider careers involving communicating or teaching STEM content? Did it change the way you view what it means to be a good science teacher?
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The boiling point show gave me analogies to use in order to better explain vaporization. Also hearing it explained many different ways by different people while they performed the show also showed me new ways to explain the concept.

Performing TBP has reinforced my belief that students can become more engaged in science when they are involved in the process. Being a good science teacher means the following to me: (1) keeping the students engaged, (2) relating science to their everyday lives, (3) making sure everyone understands a concept before I move on (of course sometimes we don't know when someone is not understanding), (4) Reinforcing the basic principles, (5) Giving students just enough information, but yet not too much. Give them the tools, materials, and support along the way and they can build the stairs to a new level of understanding. Provide them with the stairs, and they lack the motivation and necessary tools to go farther. Performing TBP has supported and reinforced these five important components of teaching science to me. It also showed me that yes, theater and science can mix into an effective learning tool. When you watch a show, and see the kids interact, you know that it is effective. The kids are drawn in and as the votes show they are learning!

It showed me that having people see what happens at the molecular level using models really increases their comprehension.

I saw that the most important part of teaching is making sure the students are excited to learn the subject and showing them that you are just as excited to teach them is the most effective way to do so. Also using analogies/models is the best way to explain something they are not able to see.

Question:
What motivated you to work on TBP?

Initially I started because I needed a third SPICE activity to fulfill my honors project requirements, and then, after going to the workshop, I found it was a lot of fun and was really effective at not only helping children understand why water boils but also teaching them the scientific method, which is fundamental to every science.

I already want to be a chemistry teacher and so I thought this would be a great way to teach children about science in a new and unique way along with gaining some self confidence and skill with speaking in front of groups of people.

I thought it was a fun new way to explain a concept. It seemed like a good way to get students excited about learning a new concept. When doing demo shows it seems like students often just want to see stuff blow up and not necessarily listen to the explanation.

Interaction with children, and teaching in a new way.

Seeing the show being performed by Holly and Chris and the rest of the FST team. The kids were so excited and drawn into the show—I would say their reaction to the show is what made me decide “hey, this is something unique they have here. I wonder how I can get involved.” Every show is so rewarding and fun. It has a certain level of creativity that keeps me thinking about what we could do differently for the next show. Seeing how much fun the FST team had with the show also motivated me to work on TBP show.

I had a great time being part of TBP! It has been a great experience and a lot of fun!

Appendix I: Presentations by Fusion Science Theater at Professional Meetings

• Oral presentation by Kerby, "Using Theater for Science Education Outreach: Fusion Science Theater" at the "Science as Performance" Conference in New York City in November 2007. Kerby was invited to attend by Dr. Brian Schwartz, P.I. of the NSF-funded "Science & the Arts" grant at City College of New York.

• Oral presentation by Kerby, "Science in a Box" at the Wisconsin Society for Science Teachers (WSST) in Lake Geneva in March 2008.

• Oral presentation by Kerby on "The Amazing Chemical Circus" at the ACS National Meeting in New Orleans in April 2008.

• Oral presentation by Kerby "Using Theater to Teach Chemistry" at the ACS National Meeting in New Orleans in April 2008.

• Oral presentation by Babiarz on "Science in a Box" at the ACS National Meeting in New Orleans in April 2008.

• Poster Session (invited in Sci Mix) by Babiarz and Kerby, on "Science in a Box" at the ACS National Meeting in New Orleans in April 2008.

• Oral Presentation by Kerby on Fusion Science Theater at Center for the Advancement of Informal Science Education (CAISE) sponsored NSF ISE PI Summit in Washington, D.C. in July 2008.

• Oral Presentation by Babiarz on "Right Brain Tools for Left Brain Learning: Using Techniques from Theater for Science Education Outreach," University of Wisconsin-Madison, Environmental Chemistry and Technology Program, May 8, 2008.

• Oral Presentation by Kerby, Babiarz, and Weiland at the Wisconsin Society of Science Teachers Conference, November 2008. The presentation included performance of "The Boiling Point" and discussion.

• Guest Lecture by Kerby during Professor Peter Hewson's Graduate Seminar on Science Curriculum, University of Wisconsin. Spring 2009.

• Poster presentation by Schmid "SPICE Performs Science in a Box" at the 2009 Fall National Meeting in Washington, D.C.

• Oral presentation by Kerby and Weiland during the session on "Bridging the Gap: Building Collaborations with High School Chemistry Clubs." 2009 Fall National ACS Meeting in Washington, D.C. FST gave a multi-media presentation that illustrated the key principles of FST

in the context of a mini-performance of "The Boiling Point."

• Poster presentation by Babiarz and Kerby "Science in a Box" at the Fall 2009 ACS National Meeting in Washington D.C.

• Oral presentation by DeKorver "Multi-sensory Techniques in Fusion Science Theater" at the Inaugural Conference for Multi-Sensory Science Education, October 23, 2009, Madison, Wisconsin. Fifty people attended the presentation with backgrounds in science education for students with disabilities.

• Oral presentation by Babiarz "Bilingual and Service-Learning Approaches to Using Theater as a Tool for Science Education Outreach" at 2010 Spring National Meeting of the American Chemical Society, March 23, 2010, San Francisco. Forty people with a common commitment to outreach as a scholarly activity attended the presentation. Symposium chair Maria Oliver-Hoy, of the University of North Carolina expressed interest in our project as a potential candidate for inclusion in the 2011 Gordon Conference on advances in ISE.

• Poster presentation by Wichman, Schmid, and Maytag "Bilingual and Service-Learning Approaches to Using Theater as a Tool for Science Education Outreach" at the Sci-Mix invited session; 2010 Spring National Meeting of the American Chemical Society, March 23, 2010, San Francisco.

• Invited Oral presentation by Weiland "Using Theater to Teach Science " at the UW Theater and Drama Graduate Student Organization's 2010 conference on "Experimenting within Theatre and Performance" April 17, 2010, Madison, Wisconsin. Twenty-five theater professionals interested in the pedagogical influence of theater on science education attended the talk, and UW Theater for Youth PhD candidate Pete Rydberg joined FST's advisory board in May 2010.

• Poster Presentation by Kerby and Babiarz "Science Investigation Shows: Using the Tools of Playwriting to Engage Audiences in All Things Science," 2010 Science and the Arts Conference sponsored by the Graduate School of the City University of New York, October 29-30, 2010, New York City. The poster will explore the value of playwriting for communicating scientific ideas to the general public.